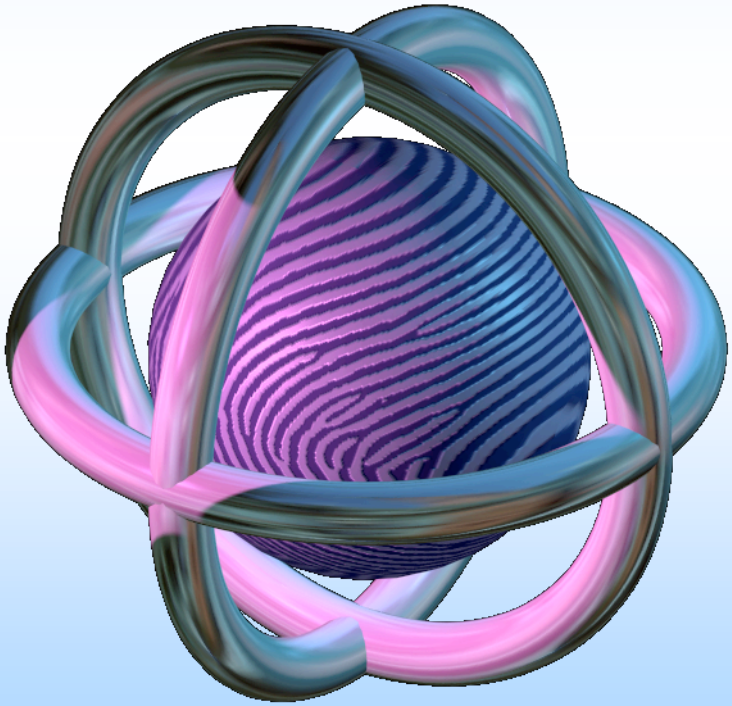
The Quality of Fingerprint Scanners and its Impact on the Accuracy of Fingerprint Recognition Algorithms

Raffaele Cappelli, Matteo Ferrara, Davide Maltoni

BIOLAB (Biometric System Laboratory)
Università degli Studi di Bologna



March 8, 2006

http://biolab.csr.unibo.it
ferrara@csr.unibo.it

Outline

- The current state-of-the-art:
  - FBI scanner certification
  - Proving Appendix F-G compliance
  - From AFIS to 1-1 personal authentication applications
- Objectives and motivation of this research
  - What is the right scanner for a given application?
  - Which are the important quality criteria?
- The on-going work at BioLab (in cooperation with CNIPA)
  - Measuring the relationship between quality criteria and accuracy
  - Defining a subset of easily-measurable quality criteria
  - Developing a toolkit for scanner quality assessment

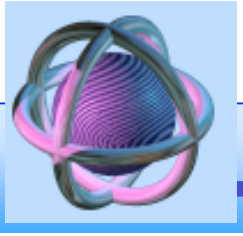
FBI scanner certification (1)

- The “master” document:
  - The FBI Electronic Fingerprint Transmission Specification (EFTS), which is the required standard for transmission of fingerprints to the FBI and many other agencies. Appendix F-G of this document is the Image Quality Standard for fingerprint scanners.
  - More recent ISO documents (e.g. ISO/IEC 19794-4:2005 – Biometric data interchange formats – Part 4: Finger image data) refer to EFTS Appendix F for defining relevant image acquisition parameters.

- Single-finger scanners cannot be certified (only AFIS slap or ten fingers scanner): http://www.fbi.gov/hq/cjisd/iafis/cert.htm

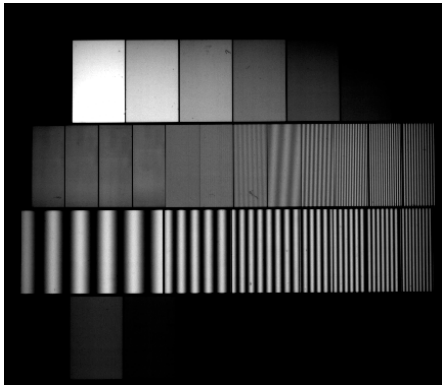
FBI scanner certification (2)

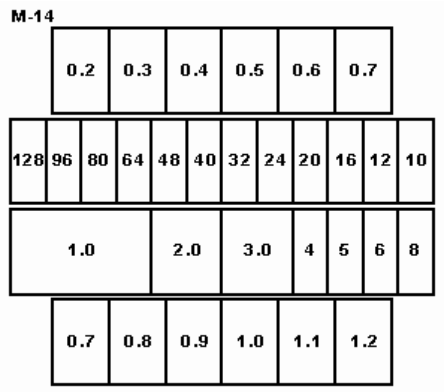
- What the certification covers
  - The fidelity in sensing a finger pattern
    - independently of the intrinsic quality of the finger (NIST Fingerprint Image Quality)
  - Quality criteria considered: those traditionally used for vision systems, acquisition and printing devices:
    - Acquisition Area
    - Resolution accuracy
    - Geometric accuracy
    - Dynamic range and gray-scale linearity
    - SNR (Signal to Noise Ratio)
    - MTF (Modulation Transfer Function)



Proving Appendix F-G compliance

- MITRE's testing procedure and support software
  - N. Nill, "Test Procedures For Verifying IAFIS Image Quality Requirements For Fingerprint Scanners And Printers", MTR050000016, MITRE, April 2005. (http://www.mitre.org/tech/mtf/tp.pdf)
  - Specific "targets" are used to measure quality criteria
    - Easy for paper scanners and printers
    - Difficult and critical for most of the live-scanners, which cannot directly sense the target without technology-specific "tricks"
    - Targets are also quite expensive
  - The testing procedure is appropriated for "expensive" large area AFIS devices, but not for single-finger live-scanners used nowadays in most civil applications.





From AFIS to 1-1 personal authentication applications (1)

- The big gap
  - No certification available for non-AFIS single-finger fingerprint scanners
  - Incomplete and ambiguous specifications are often given for large procurements
  - Sometimes Appendix F-G compliance is required because it is the only alternative

From AFIS to 1-1 personal authentication applications (2)

- The big confusion in the biometric arena
  - Some vendors self-claims FBI-compliance for single-finger scanner (not possible!)
  - A number of non-compliant scanners have been currently deployed for civil applications (border control, ID cards, etc.), where FBI compliance was actually required
  - No guidelines for comparing the quality of two non-compliant fingerprint scanners
  - Difficult to give reasonable specifications for civil applications

The right scanner for a given application

- Why FBI Appendix F-G cannot be used for any application?
  - Too stringent for several non-AFIS applications
  - Forcing producers to strictly comply to this specification significantly increases the cost of single-finger devices

- To fill the big gap we may:
  - Start from FBI Appendix F-G quality criteria
  - Understand which and to what extent criteria/constraints may be relaxed:
    - to achieve reasonable performance and interoperability for some given classes of applications
    - to allow customers to choose devices according their accuracy/cost tradeoff

The important quality criteria

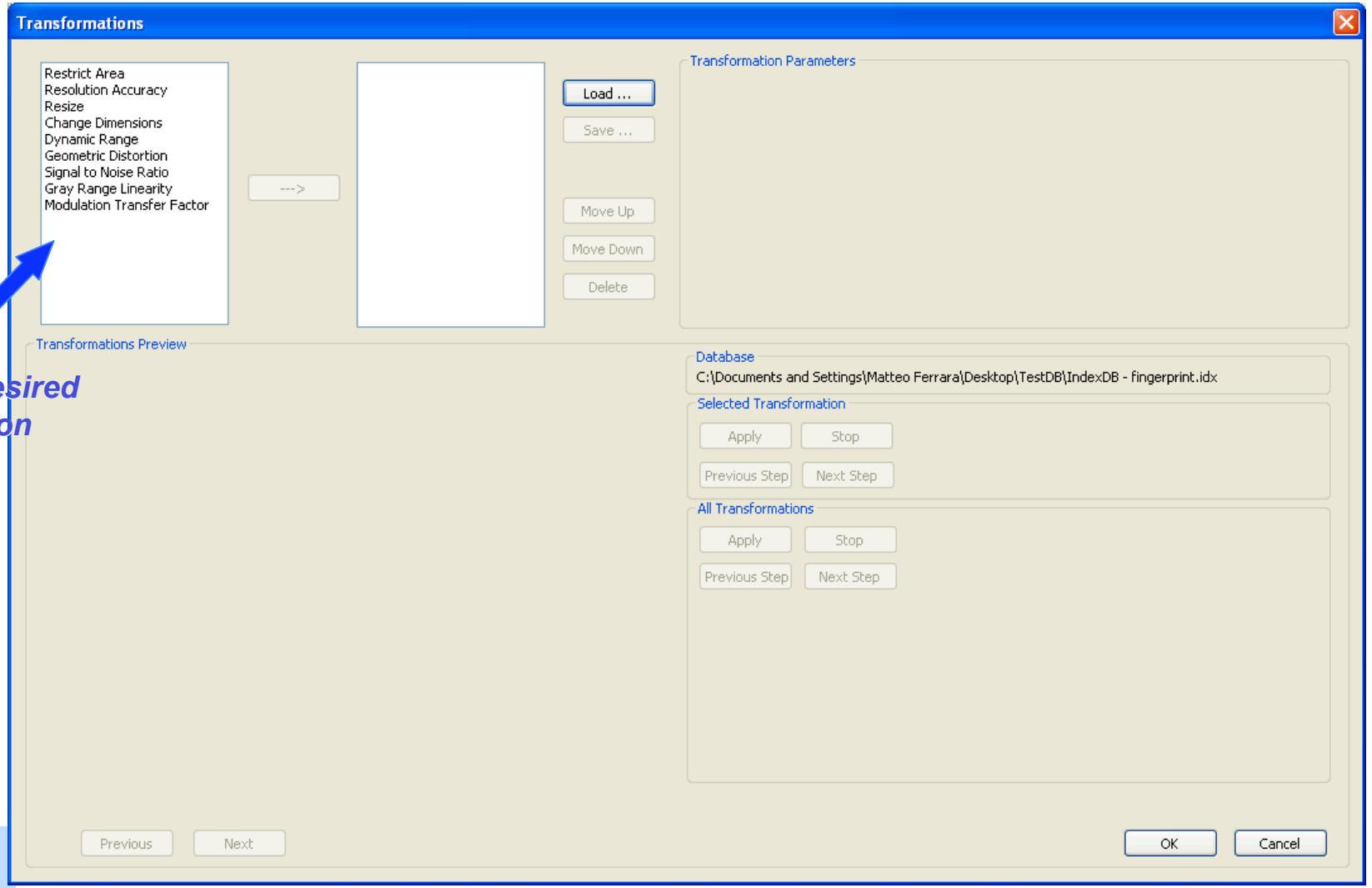
- Some of the specifications are already in the standard and/or de facto standard for the market
  - For example, image resolution: 500 DPI
  - Questioning such specifications is nowadays useless
- Other parameters appear to be too stringent:
  - SNR >= 125
  - Gray-scale linearity ...
  - MTF
- Nobody demonstrated that partially relaxing such parameters would actually cause a drop in the performance/interoperability of automatic fingerprint recognition systems

Measuring relationship between quality criteria and accuracy

- A tool has been developed for generating “degraded” versions of an input database
  - A set of databases is generated by varying, within a given range, each of the FBI quality criteria
  - The accuracy (EER, ZeroFar, etc.) of some fingerprint verification algorithms is measured over the degraded databases in an all-against-all fashion
  - For each quality criteria, the relationship between the parameter values and the average algorithm performance is studied

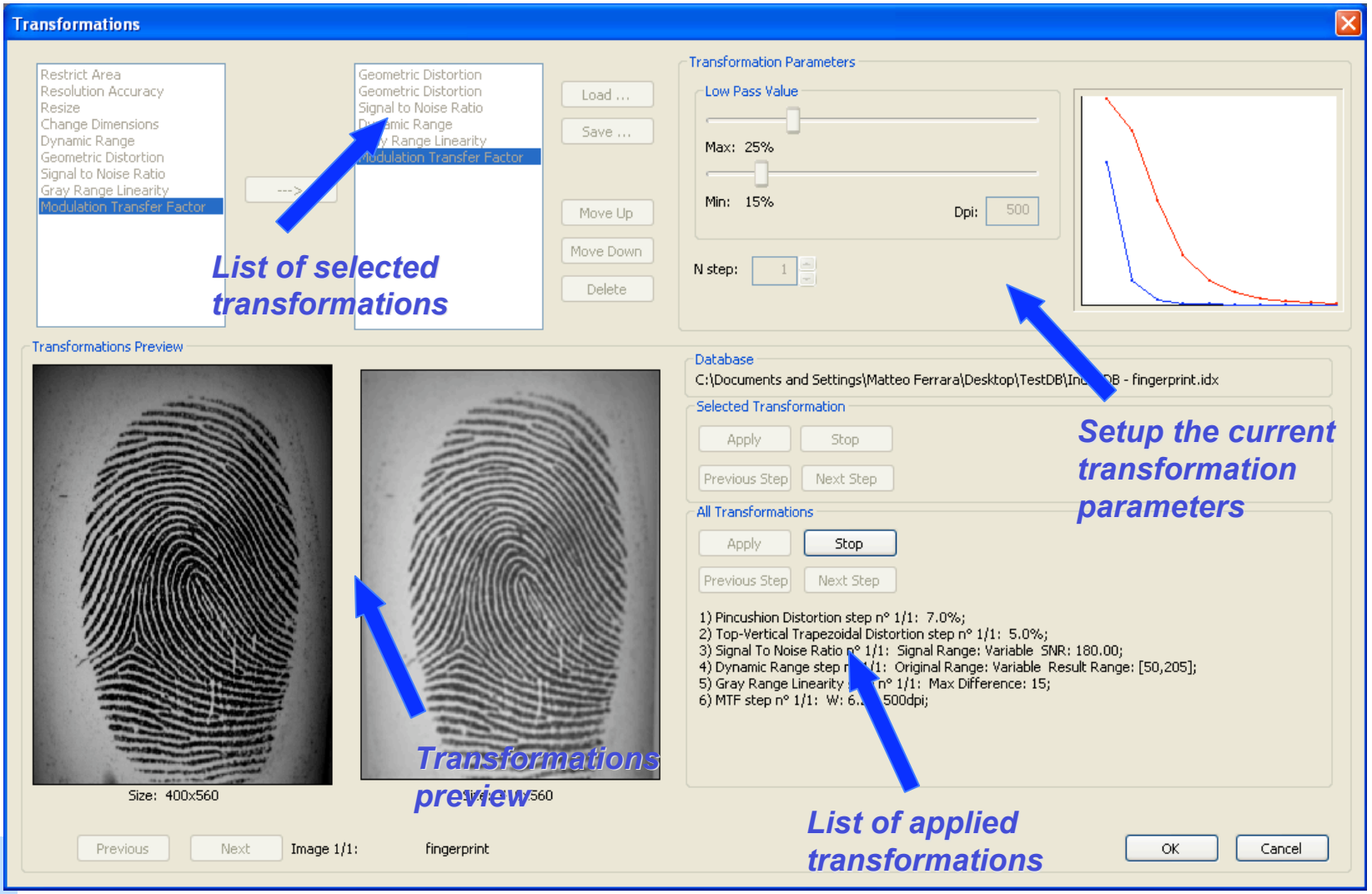
- For such tests we have to:
  - use a representative dataset
  - use a large collection of algorithms (non only minutiae-based)

Degradation quality criteria software (1)

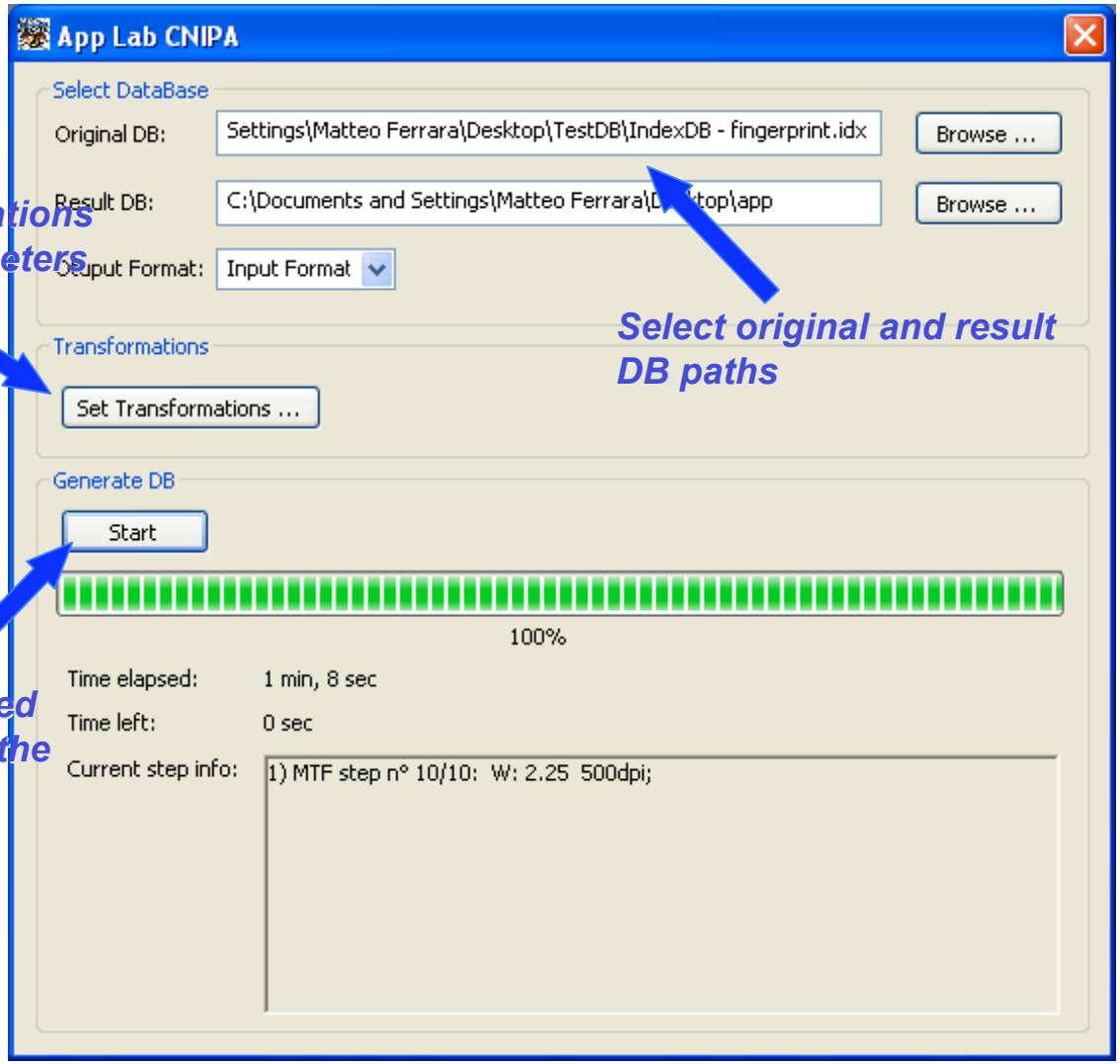


Select the desired transformation

Degradation quality criteria software (2)



Degradation quality criteria software (3)



Select the transformations and adjust the parameters

Select original and result DB paths

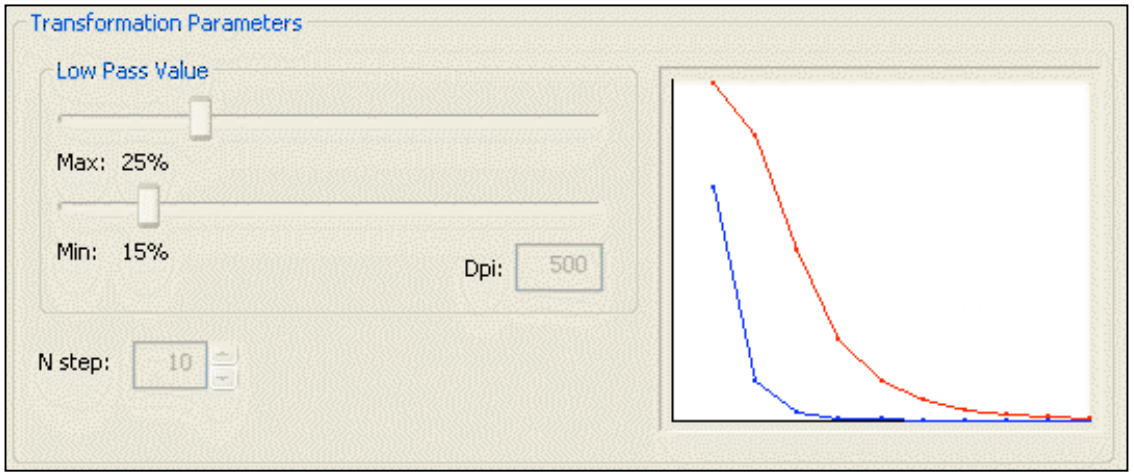
Apply all the selected transformations to the original DB

Degradation quality criteria software (4)

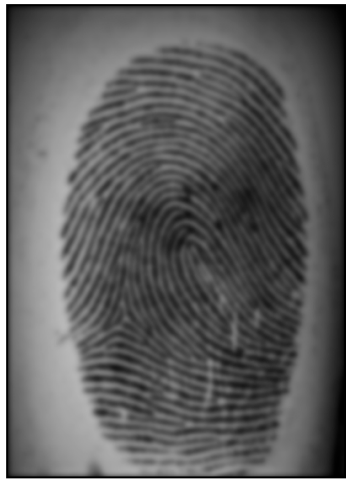
Transformation: MTF

ORIGINAL IMAGE

PARAMETERS



SOME EXAMPLES

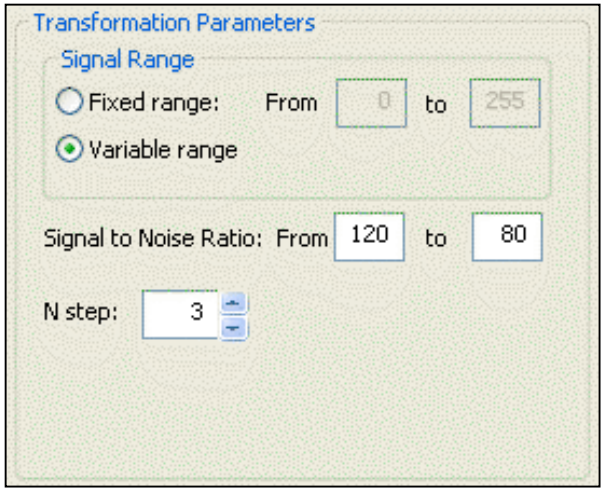


Degradation quality criteria software (5)

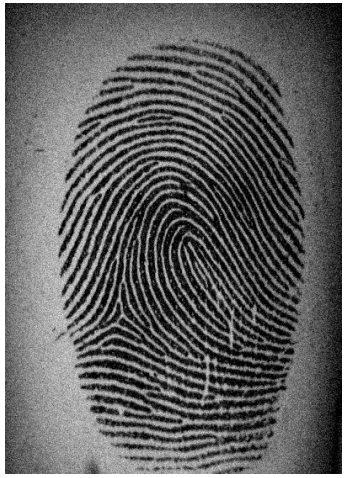
Transformation: SNR

ORIGINAL IMAGE

PARAMETERS



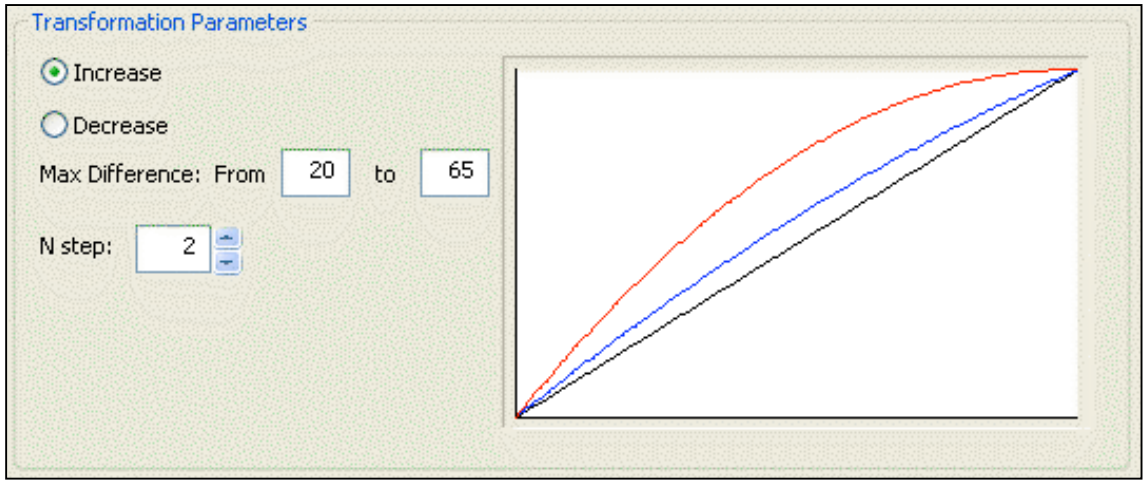
SOME EXAMPLES



Degradation quality criteria software (6)

Transformation: Gray Range Linearity

PARAMETERS



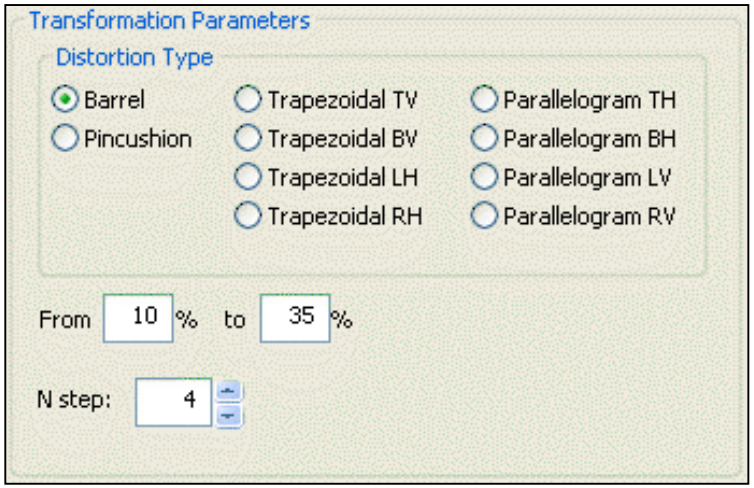
SOME EXAMPLES

Degradation quality criteria software (7)

Transformation: Geometric Distortion

ORIGINAL IMAGE

PARAMETERS



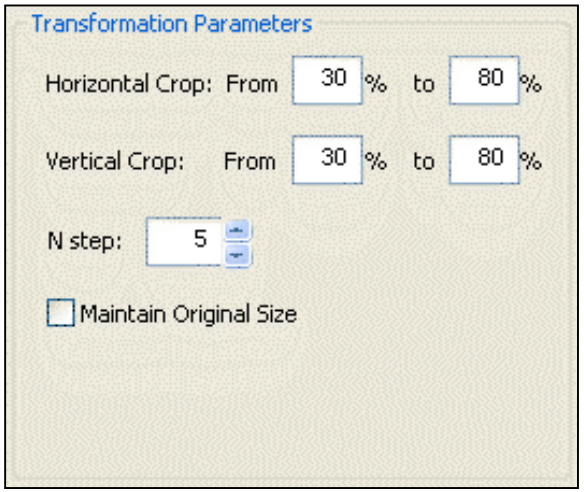
SOME EXAMPLES

Degradation quality criteria software (8)

Transformation: Restrict Area

ORIGINAL IMAGE

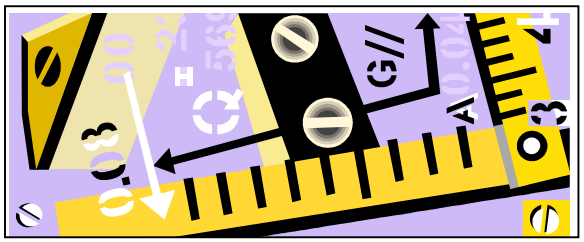
PARAMETERS



SOME EXAMPLES

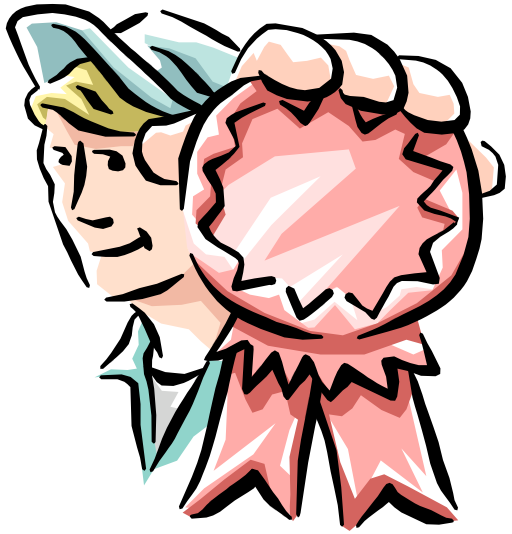
Defining a subset of easily-measurable quality criteria

- From the test results it should be possible to define:
  - How each single quality criteria actually affects the performance
  - What is the subset of FBI criteria which is really useful for non-AFIS single-finger live-scanner to be used in civil applications
  - Possibly defining classes of scanners (e.g. Class A: top, Class B: average, Class C: low-level) and characterizing such classes with the accuracy that they could guarantee
- Defining simple ways to measure the chosen criteria
  - By using simple and non-expensive targets
  - By introducing alternative measures in case using a target is not practical



Self-measuring scanner quality

- Making scanner quality-measurement simple will enable:
  - Vendors to internally measure the quality of their products and provide a sort of self-certification
  - Customers to verify the claimed quality
  - Application designers to understand what is the right class of products for a given application



Thank you for your attention

http://biolab.csr.unibo.it

ferrara@csr.unibo.it